BROOKHAVEN NATIONAL LABORATORY

Phase 5 Work Plan
Characterization of Per- and Polyfluoroalkyl Substances (PFAS) in Groundwater Downgradient of the Current and Former Firehouse Facilities

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1.0 PFAS Contamination at BNL

A class of chemicals called Per- and Polyfluoroalkyl Substances (PFAS) are emerging contaminants of concern across the United States. For Brookhaven National Laboratory (BNL), the impact that PFAS is having on groundwater quality centers around the past use of Class B firefighting foam that contained fluorinated surfactants.

In 2017, BNL's five active potable water supply wells were sampled for PFAS by the Suffolk County Department of Health Services. The samples were analyzed for the same six PFAS compounds that were evaluated under the Third Unregulated Contaminant Monitoring Rule (UCMR3) program. PFAS were detected in samples from three of the five potable supply wells (BNL-6, BNL-10 and BNL-11). Combined concentrations of the PFAS compounds perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) concentrations in the supply wells were less than the current EPA Lifetime Health Advisory Level (HAL) of 70 ng/L. The NYSDOH recently proposed establishing individual drinking water standards of 10 ng/L for PFOS and PFOA.

Following these detections, a search of available records identified eight areas where Class B firefighting foam had been released to the ground during the period of 1966 through 2008. The foam release areas include BNL's former firehouse, which was in operation from 1947 through 1985, and the current firehouse which began operations in 1986.

Starting in 2018, BNL began a multiphase characterization effort to evaluate the impacts from the releases:

- Phase 1: In May 2018, BNL installed seven temporary (Geoprobe®) wells to characterize the distribution of PFAS within the 2-year (travel time) source water contributing areas of the BNL supply wells (BNL 2018a). The primary goal of the effort was to determine whether PFAS concentrations in the source water contributing areas are at high enough levels to potentially affect future supply well operations. The results confirmed the presence of PFAS in the source water contributing areas for the wells, including the detection of PFOS and PFOA at BNL's current firehouse at combined concentrations of up to 3,124 ng/L. The 2-year capture zone of supply well #4 (BNL-4) extends to the current firehouse area. Although this well has only been in limited service for the past 10 years, BNL will prohibit future operations of this supply well unless remedial measures are taken. PFAS originating from the current firehouse is also impacting the operations of supply well #6 (BNL-6). Following a June 2018 detection of combined PFOS and PFOA concentration of 70.4 ng/L, supply well #6 has not been used for water supply operations. The locations of supply wells #4 and #6 are shown on **Figure 1**.
- Phase 2: From August through November 2018, thirty temporary groundwater monitoring wells were installed in the eight areas where firefighting foam had been released to soil (BNL 2018b). High levels of PFAS were detected in temporary wells installed at the current and former firehouse areas, with maximum combined concentrations of PFOS and PFOA of 12,440 ng/L and 5,371 ng/L, respectively.
- Phase 3: From December 2018 through January 2019, water samples were collected from on-site groundwater treatment systems, from wells downgradient of two closed landfills, in the Sewage Treatment Plant (STP) effluent, and from select Operable Unit

V monitoring wells located downgradient of the STP (BNL 2018c). In February 2019, groundwater samples were collected from 33 existing monitoring wells, and from 11 temporary wells installed along the southern site boundary (BNL 2019a). PFAS were detected in extraction wells and monitoring wells located downgradient of the former and current firehouse areas (see **Sections 2.1.1 and 2.2.1**).

- Phase 4: In January 2020, BNL started a comprehensive characterization of PFAS and 1,4-dioxane by sampling approximately 350 on-site and off-site monitoring wells, 27 off-site extraction wells and five (5) off-site groundwater treatment systems (BNL 2020). Monitoring results for permanent wells that are located downgradient of the current and former firehouse areas will be evaluated to support the Phase 5 characterization effort.

Complete monitoring results for Phases 1, 2 and 3 are summarized in the *2018 BNL Groundwater Status Report* (BNL 2019b).

2.0 Phase 5 PFAS Plume Characterization

The goal of the Phase 5 characterization effort is to obtain the data needed to support the design of groundwater treatment systems that will be required to remediate segments of Upper Glacial aquifer that are anticipated to contain the highest levels of PFAS contamination downgradient of the current and former firehouse facilities. Because previous monitoring efforts in the firehouse areas were limited to characterizing PFAS contamination, the Phase 5 effort will also include the sampling of select temporary wells for 1,4-dioxane, which has been verified as another emerging contaminate of concern at BNL. 1,4-Dioxane was used as a chemical stabilizer for the chlorinated solvent 1,1,1-trichloroehane (TCA), which has impacted groundwater quality in several areas across the BNL site. Determining whether 1,4-dioxane is present at concentrations above the proposed NYS drinking water standard of 1 µg/L is critical for the proper design of the treatment systems. The scope of the Phase 5 monitoring effort is described below.

2.1 Current Firehouse Area

The current firehouse (Building 599) has been in continuous use since 1986. Firefighters trained with Class B foam in the paved area along the north side of the firehouse, and in the adjacent grass and wooded areas (**Figure 1**). A fire extinguisher training area was located to the northwest of the firehouse, and it is believed that foam had been used in this area as well. Furthermore, as part of routine maintenance of firetruck foam systems, foam may have been released to the floor drain system in the firehouse high bay area. The floor drains are connected to BNL's sanitary system. The last known training event at the firehouse where Class B foam was used occurred in 2008. There are no available records on foam formulations or on the amount of foam that was released at this facility. In 2019, BNL replaced its inventory of Class B foam that contained PFAS with non-fluorinated foam. The older foam was sent off-site to a licensed treatment, storage and disposal (TSD) facility.

Although there is no known use of solvents at the current firehouse that could have released 1,4-dioxane, previous monitoring of the groundwater near the BNL Paint Shop located several hundred feet south did detect low levels of TCA. Furthermore, documented

releases of TCA had occurred in the Alternating Gradient Synchrotron facility located to the north-northeast.

2.1.1 Current Firehouse Monitoring Results

During 2018, seven temporary wells were installed to characterize PFAS contamination in the immediate vicinity of the current firehouse (**Figure 1**). Additionally, Western South Boundary treatment system extraction wells and monitoring wells located along the southern boundary were tested for PFAS in 2019. The monitoring results indicate:

- Combined PFOS/PFOA concentrations in the shallow groundwater exceeded the 70 ng/L HAL. The maximum combined concentration of 12,440 ng/L was detected in temporary well PFC-GP-38 at a sample depth of 52-56 feet below land surface. The individual PFOS and PFOA concentrations at this sample interval were 12,200 ng/L and 240 ng/L, respectively.
- Several other PFAS compounds were detected at high concentration. For example, PFHxS was detected at concentrations up to 3,710 ng/L, and PFBS, PFPeA, PFPeS and PFOSA were detected at concentrations above 100 ng/L.
- Combined PFOS/PFOA concentrations up to 123.7 ng/L were detected in temporary well PFC-GP-01 at a depth of 74-78 feet below land surface. At this location, the maximum PFOS concentration was 120 ng/L, and the maximum PFOA concentration was 9.2 ng/L. Well PFC-GP-01 was installed approximately 1,600 feet downgradient of the firehouse (**Figure 1**).
- PFAS that likely originated from the current firehouse were detected in OU III Western South Boundary extraction wells and monitoring wells and several temporary wells installed close to the southern site boundary. The highest PFOS and PFOA concentrations were detected in temporary well PFC-GP-45 at 6.3 ng/L and 6.7 ng/L, respectively. Sampling results for the Western South Boundary wells are presented in the *2019 BNL Groundwater Status Report* (BNL 2019b).
- To date, groundwater samples collected in the immediate vicinity of the current firehouse have not been tested for 1,4-dioxane.

The Phase 4 characterization effort currently underway includes a more comprehensive sampling of currently available monitoring wells downgradient of the current firehouse (BNL 2020).

2.1.2 Phase 5 Characterization - Current Firehouse

To better define the extent of PFAS contamination downgradient of the current firehouse, up to forty (40) temporary wells will be installed along five east-west transects. Two (2) upgradient wells will also be installed. The locations of the planned Phase 5 sampling locations are shown on **Figure 1**. A list of proposed temporary wells and monitoring parameters are presented in **Table 1**. Proposed sample depths for each temporary well are presented in **Table 2**. Samples from select temporary wells will also be analyzed for 1,4-dioxane which, if present, could have an impact on future PFAS remediation efforts. Wells to be sampled for 1,4-dioxane are identified in **Table 1**. Adjustments to the locations and sample depths of the proposed temporary wells may be made based upon subsurface conditions and the analysis of analytical results as they become available.

2.2 Former Firehouse Area

The former firehouse (former Building 99) was in operation from 1947 through 1985. Available records indicate that firefighting foam was used for training as early as 1966. Firefighters practiced with foam in a training area that was located immediately west of the firehouse (**Figure 2**). A second training area was located east of the firehouse, where firefighters would periodically practice extinguishing car fires using foam. There are no available records on foam formulations or on the amount used at the former firehouse. Most of the training area that was located to the west of the firehouse is presently occupied by Building 725 (Computational Science Initiative), which was constructed in the early 1980s. The former firehouse structure was demolished in 1986. It is unknown whether excavation activities during the construction of Building 725 resulted in the removal of PFAS contaminated soil from the area. Available records indicate that the former firehouse did not have floor drains. Exterior storm drains may have discharged to a drainage swale located several hundred feet to the southwest of the firehouse. Former potable water supply well BNL-1 was located east of the former firehouse and was in active use until September 1986.

Although there is no known use of solvents at the current firehouse that could have released 1,4-dioxane, documented releases of TCA had occurred in the Alternating Gradient Synchrotron facility located to the north-northwest. Furthermore, TCA had been released from a degreasing facility that was located at the former Supply and Material facility, in an area currently occupied by the National Synchrotron Light Source II (**Figure 2**). Solvents (primarily tetrachloroethylene) had also been released in the former Building 96 area, also located south of the former firehouse.

2.2.1 Former Firehouse Monitoring Results

During 2018, twelve temporary wells were installed to characterize PFAS contamination in the immediate vicinity of the former firehouse area (**Figure 2**). Additionally, extraction wells for groundwater treatment facilities located downgradient of the former firehouse area were tested for PFAS (e.g., Building 96, Building 452, HFBR, Middle Road and OU III South Boundary treatment systems). The monitoring results indicate:

- Combined PFOS/PFOA concentrations in the shallow groundwater exceeded the 70 ng/L HAL, with a maximum combined concentration of 5,371 ng/L detected in temporary well PFC-GP-21 at a depth of 34-38 feet below land surface. The highest individual PFOS concentration was 5,210 ng/L in PFC-GP-21 and the highest individual PFOA concentration was 736 ng/L in temporary well PFC-GP-22.
- Several other PFAS were also detected at high concentrations. For example, PFHxS was detected at concentrations up to 3,480 ng/L, and PFPeA, PFPeS PFHxA, and PFOSA were detected at concentrations above 100 ng/L.
- PFAS that likely originated from the former firehouse were detected in all four Building 96 extraction wells, the Building 452 extraction well, the inactive HFBR extraction wells, OU III Middle Road extraction wells and in South Boundary extraction wells and monitoring wells. In the south boundary area, the highest PFOS concentration was detected in monitoring well 122-10 at 65.6 ng/L and the highest PFOA concentration was detected in monitoring well 121-23 at 27.6 ng/L. Sampling results for the OU III Middle Road and South Boundary wells are presented in the *2019 BNL Groundwater Status Report* (BNL 2019b).

- To date, groundwater samples collected in the immediate vicinity of the former firehouse have not been tested for 1,4-dioxane. 1,4-Dioxane was not detected in Building 96 extraction well RTW-1 or in monitoring well 095-159 during initial testing conducted in 2017.

The Phase 4 characterization effort currently underway includes a more comprehensive sampling of currently available monitoring wells downgradient of the former firehouse (BNL 2020).

2.2.2 Phase 5 Characterization - Former Firehouse

To better define the extent of PFAS contamination downgradient of the former firehouse area, up to thirty-five (35) downgradient temporary wells will be installed along five east-west transects. Two (2) temporary upgradient wells will also be installed. The locations of the planned Phase 5 sampling locations are shown on **Figure 2**. A list of proposed temporary wells and monitoring parameters are presented in **Table 3**. Proposed sample depths for each temporary well are presented in **Table 4**. Samples from select temporary wells will also be analyzed for 1,4-dioxane which, if present, could have an impact on future PFAS remediation efforts. Temporary wells to be sampled for 1,4-dioxane are identified in **Table 3**. Adjustments to the locations and sample depths of the proposed temporary wells may be made based upon subsurface conditions and the analysis of analytical results as they become available.

3.0 Sample Collection and Analysis

3.1 Sample Collection

Groundwater samples will be collected by installing temporary wells:

- Installation and sampling protocols defined in BNL standard operating procedure EM-SOP-311, *Collection of Groundwater Samples Using Geoprobe® Wells*, will be used for the collection of groundwater samples. High Density Polyethylene (HDPE) discharge tubing shall be used. If the required sampling depths cannot be achieved by the Geoprobe® method, BNL may install vertical profile wells using standard well drilling methods (e.g., hollow stem augers). Installation and sampling protocols are defined in BNL standard operating procedure EM-SOP-310, *Collection of Groundwater Samples Using Temporary Vertical Profile Wells*.
- Groundwater samples for PFAS will be collected using analytical laboratory supplied 250 ml polypropylene sample bottles containing Trizma. Select temporary wells will also be sampled for 1,4-dioxane. Groundwater samples for 1,4-dioxane will be collected using analytical laboratory supplied 250 ml amber glass sample bottles containing sodium-bisulfate.
- All precautions listed in **Section 4.0** shall be followed to prevent potential cross contamination of the samples.
- Sample containers for 1,4-dioxane contain Teflon®-lined caps. Therefore, as a precaution PFAS samples will be collected first, followed by 1,4-dioxane samples. PFAS and 1,4-dioxane sample bottles will be kept in separate coolers during sample collection and shipment to the analytical laboratory.

- All purge water will be treated using a portable granular activated carbon unit before being discharged to the ground at the collection site.
- All temporary wells will be surveyed by a NYS licensed surveyor.

3.2 Sample Analyses

The groundwater samples will be analyzed using EPA Method 537.1 for twenty-three (23) PFAS compounds (**Table 5**). Samples from select temporary wells will also be analyzed by Method 522 for 1,4-dioxane (**Table 6**). The samples will be sent to General Engineering Laboratories (GEL), Charleston, SC, with a requested 30-day turnaround time. In some instances, 14-day turnaround times may be requested. A full (Category B) data package will be provided by GEL for both analyses. **Table 7** and **Table 8** provide a summary of the analytical methods and quality assurance samples to be collected during this effort. All data packages will undergo BNL's standardized internal verification process defined in EM-SOP-203, *Chemical Data Verification*. As an additional quality assurance check, twenty-five (25) percent of the analytical data (for approximately 300 individual samples results) will undergo a quality assurance review by an independent, contract chemist. The results of the quality assurance reviews will be documented in a Data Usability Summary Report that will be part of a final project report.

4.0 Decontamination and Cross Contamination Prevention Procedures

In addition to adhering to BNL standard operating procedures for the collection of groundwater samples described above, the following procedures shall be adhered to:

1. All Geoprobe rods will be decontaminated initially by power washing. Stainless steel check valves, and well screens will be cleaned with a solution of Alconox® followed by a water rinse.
2. As a final step in the cleaning process, the sampling equipment will be rinsed with raw, untreated water obtained directly from BNL potable supply well #7. (Note: PFAS concentration in samples from well #7 have been at trace to non-detectable levels). All equipment shall be allowed to fully air dry before use.
3. New HDPE tubing and a decontaminated stainless-steel check valve shall be used at each temporary well sample location.
4. New nitrile gloves shall be worn between each sample interval.
5. Only clean cotton or synthetic clothes shall be worn – preferably washed more than six times, and without the use of fabric softeners. No waterproof or insecticide treated clothing, boots or rain jackets made or treated with Teflon® products shall be used at the collection site. This includes all Gore-Tex® and Tyvek® products.
6. Field personnel shall not apply moisturizers, hand creams, sunblock or insect repellants to hands or face on the day of sampling. Packaged food or aluminum foil shall not be allowed in the work area.
7. Field notes shall be taken using a computer tablet or by using ink pens on non-waterproof plain paper attached to a metal clipboard. Sharpies and markers shall

not be used. Transcribe field notes to Chain-of-Custody forms and official field books when back in the office after the collection process.

8. Only analytical laboratory supplied sample bottles shall be used.
9. Container labels shall be applied before going into the field.
10. Only analytical laboratory supplied PFAS-free water shall be used for field reagent blanks and equipment blanks.
11. Each sample container shall be placed in separate polypropylene zip-lock bags.
12. For the shipping coolers, only regular crushed ice packaged in polypropylene zip-lock plastic bags shall be used.
13. Only shipping coolers that were used to ship sample containers for this project shall be used. The shipping coolers shall be taped shut and banded before shipping samples to the analytical laboratory.

5.0 References

BNL 2018a. Work Plan for the Characterization of Per-fluorinated Compounds in Groundwater within the Source Water Contributing Areas of BNL Supply Wells. Brookhaven National Laboratory, Upton, New York. March 26, 2018.

BNL 2018b. Phase 2 Work Plan for the Characterization of Per- and Polyfluoroalkyl Substances (PFAS) in Known or Suspected Firefighting Foam Release Areas. Brookhaven National Laboratory, Upton, New York. July 31, 2018.

BNL 2018c. Phase 3 Work Plan, Testing for Per- and Polyfluoroalkyl Substances (PFAS) in Groundwater Treatment Systems, Sewage Treatment Plant Effluent, Landfill Monitoring Wells, and OU V Monitoring Wells. Brookhaven National Laboratory, Upton, New York. November 30, 2018.

BNL 2019a. Addendum to the Phase 3 Work Plan, Testing for Per- and Polyfluoroalkyl Substances (PFAS) in Groundwater Treatment Systems, Sewage Treatment Plant Effluent, Landfill Monitoring Wells, South Boundary Monitoring Wells and OU V Monitoring Wells. Brookhaven National Laboratory, Upton, New York. March 5, 2019.

BNL 2019b. 2018 Site Environmental Report, Volume 2, Groundwater Status Report. Brookhaven National Laboratory, Upton, New York. June 2019.

BNL 2020. Phase 4 Work Plan, Characterization of Per- and Polyfluoroalkyl Substances (PFAS) and 1,4-Dioxane in Select On-Site and Off-Site Monitoring Wells and Off-Site Extraction Wells and Treatment Systems. Brookhaven National Laboratory, Upton, New York. January 27, 2020.

USEPA 2008. Method 522, Determination of 1,4-dioxane in Drinking Water by Solid Phase Extraction (SPE) and Gas Chromatography/Mass Spectrometry (GC/MS) with Selected Ion Monitoring (SIM). EPA Document #: EPA/600/R-08/101. September 2008.

USEPA 2018. Method 537.1, Determination of Selected Per- and Polyfluoroalkyl Substances in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS). EPA Document #: EPA/600/R-18/352. November 2018.

Table 1
Phase 5 Work Plan
Brookhaven National Laboratory
Current Firehouse Plume Characterization
List of Proposed Temporary Wells

Temporary Well No.	Analytical Parameters	Number of Planned Sample Intervals
PFC-GP-55 (a)	PFAS	9
PFC-GP-56 (a)	PFAS	9
PFC-GP-57	PFAS	9
PFC-GP-58	PFAS & 1,4-Dioxane	9
PFC-GP-59	PFAS	9
PFC-GP-60	PFAS & 1,4-Dioxane	9
PFC-GP-61	PFAS	9
PFC-GP-62	PFAS & 1,4-Dioxane	9
PFC-GP-63	PFAS	9
PFC-GP-64	PFAS	8
PFC-GP-65	PFAS & 1,4-Dioxane	8
PFC-GP-66	PFAS	8
PFC-GP-67	PFAS & 1,4-Dioxane	8
PFC-GP-68	PFAS	8
PFC-GP-69	PFAS & 1,4-Dioxane	8
PFC-GP-70	PFAS	8
PFC-GP-71	PFAS	9
PFC-GP-72	PFAS & 1,4-Dioxane	9
PFC-GP-73	PFAS	9
PFC-GP-74	PFAS & 1,4-Dioxane	9
PFC-GP-75	PFAS	9
PFC-GP-76	PFAS & 1,4-Dioxane	9
PFC-GP-77	PFAS	9
PFC-GP-78	PFAS	9
PFC-GP-79	PFAS	9
PFC-GP-80	PFAS & 1,4-Dioxane	9
PFC-GP-81	PFAS	9
PFC-GP-82	PFAS & 1,4-Dioxane	9
PFC-GP-83	PFAS	9
PFC-GP-84	PFAS & 1,4-Dioxane	9
PFC-GP-85	PFAS	9
PFC-GP-86	PFAS & 1,4-Dioxane	9
PFC-GP-87	PFAS	9
PFC-GP-88	PFAS	10
PFC-GP-89	PFAS & 1,4-Dioxane	10
PFC-GP-90	PFAS	10
PFC-GP-91	PFAS & 1,4-Dioxane	10
PFC-GP-92	PFAS	10
PFC-GP-93	PFAS & 1,4-Dioxane	10
PFC-GP-94	PFAS	10
PFC-GP-95	PFAS & 1,4-Dioxane	10
PFC-GP-96	PFAS	10

(a) Upgradient well

Table 2. Phase 5, Current Firehouse, Proposed Geoprobe Sample Collection Intervals[1].

Well	PFC-GP-55	PFC-GP-56	PFC-GP-57	PFC-GP-58	PFC-GP-59	PFC-GP-60	PFC-GP-61	PFC-GP-62	PFC-GP-63
Land Surface Elev. (Feet AMSL)	90	90	90	90	90	90	90	90	90
Water Table Elev. (Feet AMSL)	44	44	44	44	44	44	44	44	44
Depth to Water (Feet BLS)	46	46	46	46	46	46	46	46	46
Analysis	PFAS	PFAS	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS
Sample Depth (Feet BLS)	50-54	50-54	50-54	50-54	50-54	50-54	50-54	50-54	50-54
	60-64	60-64	60-64	60-64	60-64	60-64	60-64	60-64	60-64
	70-74	70-74	70-74	70-74	70-74	70-74	70-74	70-74	70-74
	80-84	80-84	80-84	80-84	80-84	80-84	80-84	80-84	80-84
	90-94	90-94	90-94	90-94	90-94	90-94	90-94	90-94	90-94
	100-104	100-104	100-104	100-104	100-104	100-104	100-104	100-104	100-104
	110-114	110-114	110-114	110-114	110-114	110-114	110-114	110-114	110-114
	120-124	120-124	120-124	120-124	120-124	120-124	120-124	120-124	120-124
	130-134	130-134	130-134	130-134	130-134	130-134	130-134	130-134	130-134

1) Sample intervals may be adjusted based upon subsurface conditions and depth to water at the time of sample collection

Table 2. Phase 5, Current Firehouse, Proposed Geoprobe Sample Collection Intervals[1].

Well	PFC-GP-64	PFC-GP-65	PFC-GP-66	PFC-GP-67	PFC-GP-68	PFC-GP-69	PFC-GP-70
Land Surface Elev. (Feet AMSL)	108	108	108	108	108	108	108
Water Table Elev. (Feet AMSL)	43	43	43	43	43	43	43
Depth to Water (Feet BLS)	65	65	65	65	65	65	65
Analysis	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS
Sample Depth (Feet BLS)	70-74	70-74	70-74	70-74	70-74	70-74	70-74
	80-84	80-84	80-84	80-84	80-84	80-84	80-84
	90-94	90-94	90-94	90-94	90-94	90-94	90-94
	100-104	100-104	100-104	100-104	100-104	100-104	100-104
	110-114	110-114	110-114	110-114	110-114	110-114	110-114
	120-124	120-124	120-124	120-124	120-124	120-124	120-124
	130-134	130-134	130-134	130-134	130-134	130-134	130-134
	140-144	140-144	140-144	140-144	140-144	140-144	140-144

1) Sample intervals may be adjusted based upon subsurface conditions and depth to water at the time of sample collection

Table 2. Phase 5, Current Firehouse, Proposed Geoprobe Sample Collection Intervals[1].

Well	PFC-GP-71	PFC-GP-72	PFC-GP-73	PFC-GP-74	PFC-GP-75	PFC-GP-76	PFC-GP-77
Land Surface Elev. (Feet AMSL)	108	108	108	108	108	108	108
Water Table Elev. (Feet AMSL)	43	43	43	43	43	43	43
Depth to Water (Feet BLS)	65	65	65	65	65	65	65
Analysis	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS
Sample Depth (Feet BLS)	70-74	70-74	70-74	70-74	70-74	70-74	70-74
	80-84	80-84	80-84	80-84	80-84	80-84	80-84
	90-94	90-94	90-94	90-94	90-94	90-94	90-94
	100-104	100-104	100-104	100-104	100-104	100-104	100-104
	110-114	110-114	110-114	110-114	110-114	110-114	110-114
	120-124	120-124	120-124	120-124	120-124	120-124	120-124
	130-134	130-134	130-134	130-134	130-134	130-134	130-134
	140-144	140-144	140-144	140-144	140-144	140-144	140-144
	150-154	150-154	150-154	150-154	150-154	150-154	150-154

1) Sample intervals may be adjusted based upon subsurface conditions and depth to water at the time of sample collection

Table 2. Phase 5, Current Firehouse, Proposed Geoprobe Sample Collection Intervals[1].

Well	PFC-GP-78	PFC-GP-79	PFC-GP-80	PFC-GP-81	PFC-GP-82	PFC-GP-83	PFC-GP-84	PFC-GP-85	PFC-GP-86	PFC-GP-87
Land Surface Elev. (Feet AMSL)	109	109	109	109	109	109	109	109	109	109
Water Table Elev. (Feet AMSL)	42	42	42	42	42	42	42	42	42	42
Depth to Water (Feet BLS)	67	67	67	67	67	67	67	67	67	67
Analysis	PFAS	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS
Sample Depth (Feet BLS)	70-74	70-74	70-74	70-74	70-74	70-74	70-74	70-74	70-74	70-74
	80-84	80-84	80-84	80-84	80-84	80-84	80-84	80-84	80-84	80-84
	90-94	90-94	90-94	90-94	90-94	90-94	90-94	90-94	90-94	90-94
	100-104	100-104	100-104	100-104	100-104	100-104	100-104	100-104	100-104	100-104
	110-114	110-114	110-114	110-114	110-114	110-114	110-114	110-114	110-114	110-114
	120-124	120-124	120-124	120-124	120-124	120-124	120-124	120-124	120-124	120-124
	130-134	130-134	130-134	130-134	130-134	130-134	130-134	130-134	130-134	130-134
	140-144	140-144	140-144	140-144	140-144	140-144	140-144	140-144	140-144	140-144
	150-154	150-154	150-154	150-154	150-154	150-154	150-154	150-154	150-154	150-154

1) Sample intervals may be adjusted based upon subsurface conditions and depth to water at the time of sample collection

Table 2. Phase 5, Current Firehouse, Proposed Geoprobe Sample Collection Intervals[1].

Well	PFC-GP-88	PFC-GP-89	PFC-GP-90	PFC-GP-11	PFC-GP-92	PFC-GP-93	PFC-GP-94	PFC-GP-95	PFC-GP-96
Land Surface Elev. (Feet AMSL)	91	91	91	91	91	91	91	91	91
Water Table Elev. (Feet AMSL)	41	41	41	41	41	41	41	41	41
Depth to Water (Feet BLS)	50	50	50	50	50	50	50	50	50
Analysis	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS
Sample Depth (Feet BLS)	60-64	60-64	60-64	60-64	60-64	60-64	60-64	60-64	60-64
	70-74	70-74	70-74	70-74	70-74	70-74	70-74	70-74	70-74
	80-84	80-84	80-84	80-84	80-84	80-84	80-84	80-84	80-84
	90-94	90-94	90-94	90-94	90-94	90-94	90-94	90-94	90-94
	100-104	100-104	100-104	100-104	100-104	100-104	100-104	100-104	100-104
	110-114	110-114	110-114	110-114	110-114	110-114	110-114	110-114	110-114
	120-124	120-124	120-124	120-124	120-124	120-124	120-124	120-124	120-124
	130-134	130-134	130-134	130-134	130-134	130-134	130-134	130-134	130-134
	140-144	140-144	140-144	140-144	140-144	140-144	140-144	140-144	140-144
	150-154	150-154	150-154	150-154	150-154	150-154	150-154	150-154	150-154

1) Sample intervals may be adjusted based upon subsurface conditions and depth to water at the time of sample collection

Table 3
Phase 5 Work Plan
Brookhaven National Laboratory
Former Firehouse Plume Characterization
List of Proposed Temporary Wells

Temporary Well No.	Analytical Parameters	Number of Planned Sample Intervals
PFC-GP-97	PFAS	9
PFC-GP-98	PFAS & 1,4-Dioxane	9
PFC-GP-99	PFAS	9
PFC-GP-100	PFAS & 1,4-Dioxane	9
PFC-GP-101	PFAS	9
PFC-GP-102	PFAS & 1,4-Dioxane	9
PFC-GP-103	PFAS	10
PFC-GP-104	PFAS	10
PFC-GP-105	PFAS & 1,4-Dioxane	10
PFC-GP-106	PFAS	10
PFC-GP-107	PFAS & 1,4-Dioxane	10
PFC-GP-108	PFAS	10
PFC-GP-109	PFAS	10
PFC-GP-110	PFAS & 1,4-Dioxane	10
PFC-GP-111	PFAS	10
PFC-GP-112	PFAS & 1,4-Dioxane	10
PFC-GP-113	PFAS	10
PFC-GP-114	PFAS & 1,4-Dioxane	10
PFC-GP-115	PFAS	10
PFC-GP-116	PFAS	13
PFC-GP-117	PFAS & 1,4-Dioxane	13
PFC-GP-118	PFAS	12
PFC-GP-119	PFAS & 1,4-Dioxane	12
PFC-GP-120	PFAS	12
PFC-GP-121	PFAS & 1,4-Dioxane	12
PFC-GP-122	PFAS	12
PFC-GP-123	PFAS & 1,4-Dioxane	12
PFC-GP-124	PFAS	13
PFC-GP-125	PFAS & 1,4-Dioxane	13
PFC-GP-126	PFAS	13
PFC-GP-127	PFAS & 1,4-Dioxane	13
PFC-GP-128	PFAS	13
PFC-GP-129	PFAS & 1,4-Dioxane	13
PFC-GP-130	PFAS	13
PFC-GP-131	PFAS	13
PFC-GP-132 (a)	PFAS	9
PFC-GP-133 (a)	PFAS	9

(a) Upgradient well

Table 4. Phase 5, Former Firehouse, Proposed Geoprobe Sample Collection Intervals[1].

Well	PFC-GP-132	PFC-GP-133	PFC-GP-97	PFC-GP-98	PFC-GP-99	PFC-GP-100	PFC-GP-101	PFC-GP-102
Land Surface Elev. (Feet AMSL)	74	74	74	74	74	74	74	74
Water Table Elev. (Feet AMSL)	43	43	43	43	43	43	43	43
Depth to Water (Feet BLS)	31	31	31	31	31	31	31	31
Analysis	PFAS	PFAS	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D
Sample Depth (Feet BLS)	30-34	30-34	30-34	30-34	30-34	30-34	30-34	30-34
	40-44	40-44	40-44	40-44	40-44	40-44	40-44	40-44
	50-54	50-54	50-54	50-54	50-54	50-54	50-54	50-54
	60-64	60-64	60-64	60-64	60-64	60-64	60-64	60-64
	70-74	70-74	70-74	70-74	70-74	70-74	70-74	70-74
	80-84	80-84	80-84	80-84	80-84	80-84	80-84	80-84
	90-94	90-94	90-94	90-94	90-94	90-94	90-94	90-94
	100-104	100-104	100-104	100-104	100-104	100-104	100-104	100-104
	110-114	110-114	110-114	110-114	110-114	110-114	110-114	110-114

1) Sample intervals may be adjusted based upon subsurface conditions and depth to water at the time of sample collection

Table 4. Phase 5, Former Firehouse, Proposed Geoprobe Sample Collection Intervals[1].

Well	PFC-GP-103	PFC-GP-104	PFC-GP-105	PFC-GP-106	PFC-GP-107	PFC-GP-108
Land Surface Elev. (Feet AMSL)	66	66	66	70	72	72
Water Table Elev. (Feet AMSL)	42	42	42	42	42	42
Depth to Water (Feet BLS)	24	24	24	28	30	30
Analysis	PFAS	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS
Sample Depth (Feet BLS)	30-34	30-34	30-34	30-34	30-34	30-34
	40-44	40-44	40-44	40-44	40-44	40-44
	50-54	50-54	50-54	50-54	50-54	50-54
	60-64	60-64	60-64	60-64	60-64	60-64
	70-74	70-74	70-74	70-74	70-74	70-74
	80-84	80-84	80-84	80-84	80-84	80-84
	90-94	90-94	90-94	90-94	90-94	90-94
	100-104	100-104	100-104	100-104	100-104	100-104
	110-114	110-114	110-114	110-114	110-114	110-114
	120-124	120-124	120-124	120-124	120-124	120-124

1) Sample intervals may be adjusted based upon subsurface conditions and depth to water at the time of sample collection

Table 4. Phase 5, Former Firehouse, Proposed Geoprobe Sample Collection Intervals[1].

Well	PFC-GP-109	PFC-GP-110	PFC-GP-111	PFC-GP-112	PFC-GP-113	PFC-GP-114	PFC-GP-115
Land Surface Elev. (Feet AMSL)	65	65	65	65	65	65	65
Water Table Elev. (Feet AMSL)	42	42	42	42	42	42	42
Depth to Water (Feet BLS)	23	23	23	23	23	23	23
Analysis	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS
Sample Depth (Feet BLS)	30-34	30-34	30-34	30-34	30-34	30-34	30-34
	40-44	40-44	40-44	40-44	40-44	40-44	40-44
	50-54	50-54	50-54	50-54	50-54	50-54	50-54
	60-64	60-64	60-64	60-64	60-64	60-64	60-64
	70-74	70-74	70-74	70-74	70-74	70-74	70-74
	80-84	80-84	80-84	80-84	80-84	80-84	80-84
	90-94	90-94	90-94	90-94	90-94	90-94	90-94
	100-104	100-104	100-104	100-104	100-104	100-104	100-104
	110-114	110-114	110-114	110-114	110-114	110-114	110-114
	120-124	120-124	120-124	120-124	120-124	120-124	120-124

1) Sample intervals may be adjusted based upon subsurface conditions and depth to water at the time of sample collection

Table 4. Phase 5, Former Firehouse, Proposed Geoprobe Sample Collection Intervals[1].

Well	PFC-GP-116	PFC-GP-117	PFC-GP-118	PFC-GP-119	PFC-GP-120	PFC-GP-121	PFC-GP-122	PFC-GP-123
Land Surface Elev. (Feet AMSL)	55	55	62	62	62	67	70	70
Water Table Elev. (Feet AMSL)	41	41	41	41	41	41	41	41
Depth to Water (Feet BLS)	14	14	21	21	21	26	29	29
Analysis	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D
Sample Depth (Feet BLS)	20-24	20-24						
	30-34	30-34	30-34	30-34	30-34	30-34	30-34	30-34
	40-44	40-44	40-44	40-44	40-44	40-44	40-44	40-44
	50-54	50-54	50-54	50-54	50-54	50-54	50-54	50-54
	60-64	60-64	60-64	60-64	60-64	60-64	60-64	60-64
	70-74	70-74	70-74	70-74	70-74	70-74	70-74	70-74
	80-84	80-84	80-84	80-84	80-84	80-84	80-84	80-84
	90-94	90-94	90-94	90-94	90-94	90-94	90-94	90-94
	100-104	100-104	100-104	100-104	100-104	100-104	100-104	100-104
	110-114	110-114	110-114	110-114	110-114	110-114	110-114	110-114
	120-124	120-124	120-124	120-124	120-124	120-124	120-124	120-124
	130-134	130-134	130-134	130-134	130-134	130-134	130-134	130-134
	140-144	140-144	140-144	140-144	140-144	140-144	140-144	140-144

1) Sample intervals may be adjusted based upon subsurface conditions and depth to water at the time of sample collection

Table 4. Phase 5, Former Firehouse, Proposed Geoprobe Sample Collection Intervals[1].

Well	PFC-GP-124	PFC-GP-125	PFC-GP-126	PFC-GP-127	PFC-GP-128	PFC-GP-129	PFC-GP-130	PFC-GP-131
Land Surface Elev. (Feet AMSL)	67	67	67	67	67	67	67	67
Water Table Elev. (Feet AMSL)	41	41	41	41	41	41	41	41
Depth to Water (Feet BLS)	26	26	26	26	26	26	26	26
Analysis	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS & 1,4-D	PFAS	PFAS
Sample Depth (Feet BLS)	30-34	30-34	30-34	30-34	30-34	30-34	30-34	30-34
	40-44	40-44	40-44	40-44	40-44	40-44	40-44	40-44
	50-54	50-54	50-54	50-54	50-54	50-54	50-54	50-54
	60-64	60-64	60-64	60-64	60-64	60-64	60-64	60-64
	70-74	70-74	70-74	70-74	70-74	70-74	70-74	70-74
	80-84	80-84	80-84	80-84	80-84	80-84	80-84	80-84
	90-94	90-94	90-94	90-94	90-94	90-94	90-94	90-94
	100-104	100-104	100-104	100-104	100-104	100-104	100-104	100-104
	110-114	110-114	110-114	110-114	110-114	110-114	110-114	110-114
	120-124	120-124	120-124	120-124	120-124	120-124	120-124	120-124
	130-134	130-134	130-134	130-134	130-134	130-134	130-134	130-134
	140-144	140-144	140-144	140-144	140-144	140-144	140-144	140-144
	150-154	150-154	150-154	150-154	150-154	150-154	150-154	150-154

1) Sample intervals may be adjusted based upon subsurface conditions and depth to water at the time of sample collection

Table 5. PFAS Analysis Summary

General Engineering Laboratories EPA Method 537.1		Water Detection Limits	
Parameter	**CAS Number**	**MDL ng/L**	**PQL ng/L**
Perfluorooctanesulfonate (PFOS)	1763-23-1	0.66	2
Perfluoroundecanoic acid (PFUdA)	2058-94-8	0.72	2
N-methylperfluoro-1-octanesulfonamidoacetic acid	2355-31-9	1.32	4
Perfluoropentanoic acid (PFPeA)	2706-90-3	0.66	2
Perfluoropentanesulfonate (PFPeS)	2706-91-4	0.66	1.88
N-ethylperfluoro-1-octanesulfonamidoacetic acid	2991-50-6	1.32	4
Perfluorohexanoic acid (PFHxA)	307-24-4	0.66	2
Perfluorododecanoic acid (PFDoA)	307-55-1	0.66	2
Perfluorooctanoic acid (PFOA)	335-67-1	0.66	2
Perfluorodecanoic acid (PFDA)	335-76-2	0.66	2
Perfluorodecanesulfonate (PFDS)	335-77-3	0.66	1.94
Perfluorohexanesulfonate (PFHxS)	355-46-4	0.66	1.82
Perfluorobutyric acid (PFBA)	375-22-4	0.82	2
Perfluorobutanesulfonate (PFBS)	375-73-5	0.8	1.78
Perfluoroheptanoic acid (PFHpA)	375-85-9	0.66	2
Perfluoroheptanesulfonate (PFHpS)	375-92-8	0.66	1.9
Perfluorononanoic acid (PFNA)	375-95-1	0.66	2
Perfluorotetradecanoic acid (PFTeDA)	376-06-7	0.66	2
Perfluorononanesulfonate (PFNS)	68259-12-1	0.7	1.92
Perfluorotridecanoic acid (PFTrDA)	72629-94-8	0.66	2
Perfluorooctanesulfonamide (PFOSA)	754-91-6	0.66	1.86
6:2 Fluorotelomer sulfonate (6:2 FTS)	27619-97-2	0.66	1.9
8:2 Fluorotelomer sulfonate (8:2 FTS)	39108-34-4	1.32	3.84

MDL: Minimum detection limit
PQL: Practical quantitation limit
ng/L: nanograms per liter

Table 6. 1,4-Dioxane Analysis Summary

General Engineering Laboratories EPA Method 522		Water Detection Limits	
Parameter	**CAS Number**	**MDL µg/L**	**PQL µg/L**
1,4-Dioxane	123-91-1	0.1	0.2

MDL: Minimum detection limit
PQL: Practical quantitation limit
µg/L: micrograms per liter

Table 7. Analytical Methods/Quality Assurance Summary for PFAS.

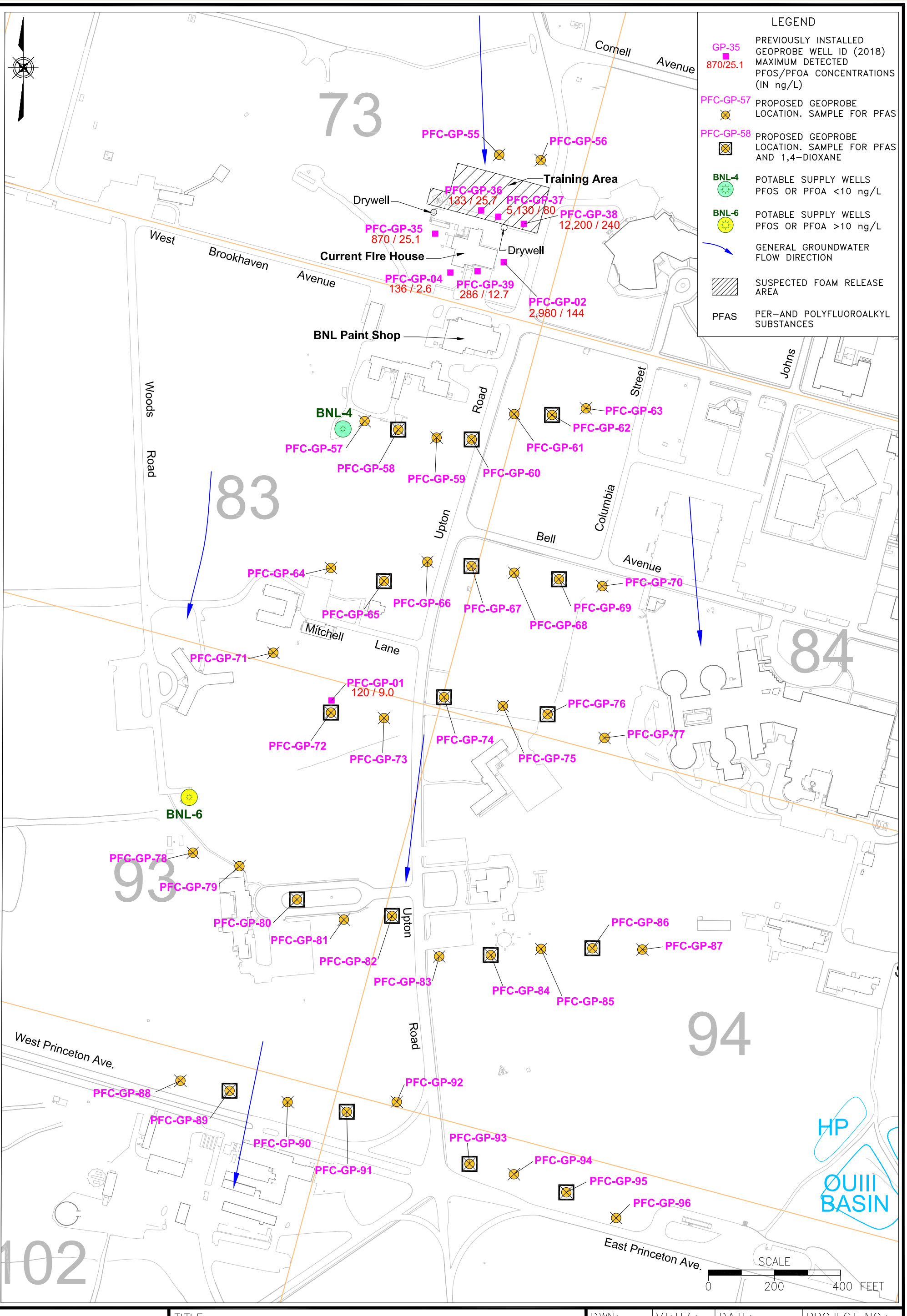
Samples	Parameters/Frequency
Matrix type	Groundwater
Number of samples	Geoprobe® wells = 77 Total sample intervals= ~970
Analytical parameters	23 PFAS (see Table 3)
Analytical method	EPA Method 537.1 by LC-MS/MS
Number of equipment blanks	One per 10 sample locations (Note 1)
Number of field reagent blanks - supplied by GEL.	Two, 250 ml polypropylene bottles. One per sample shipment
Number of MS/MSDs	One set per every 20 sample intervals
Number of duplicate samples	One per every 20 sample intervals
Sample preservation	Trizma Samples maintained to ≤10°C (Note 2)
Sample container volume and type	Two, 250 ml polypropylene bottles per sample interval
Sample holding times	Time to extraction = 14 days Time to analyze = 28 days

Note 1: Equipment blank on decontaminated Geoprobe® rods/screens.
Note 2: Sample temperature requirements as defined in EPA Method 537.1 (USEPA, 2018). Samples must not exceed 10°C during the first 48 hours after collection, then be maintained by the analytical laboratory at ≤6°C (but not frozen) until extraction. BNL samples typically arrive at GEL Laboratories at temperatures of 1 to 4 °C.

Table 8. Analytical Methods/Quality Assurance Summary for 1,4-dioxane.

Samples	Parameters/Frequency
Matrix type	Groundwater
Number of well samples	Geoprobe® wells = 32 Total sample intervals = ~420
Analytical parameters	1,4-dioxane (see Table 4)
Analytical method	EPA Method 522 by GC-MS/SIM
Number of equipment blanks	One per 10 sample locations (Note 1)
Number of trip blanks	One per sample shipment
Number of MS/MSDs	One set per every 20 sample intervals
Number of duplicate samples	One per every 20 sample intervals
Sample preservation	Sodium bisulfate Samples maintained to <10°C (Note 2)
Sample container volume and type	One, 250 ml amber glass bottle with Teflon septum per sample interval
Sample holding times	Time to extraction = 28 days Time to analyze = 28 days after extraction

Note 1: Equipment blank on decontaminated Geoprobe® rods/screens.
Note 2: Sample temperature requirements as defined in EPA Method 522 (USEPA, 2008). Samples must not exceed 10°C during the first 48 hours after collection, then be maintained by the analytical laboratory at ≤6°C (but not frozen) until extraction.



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BROOKHAVEN NATIONAL LABORATORY

ENVIRONMENTAL PROTECTION DIVISION

TITLE:

CURRENT FIREHOUSE AREA PFAS AND 1,4-DIOXANE CHARACTERIZATION

PROPOSED PHASE 5 GEOPROBE LOCATIONS

DWN:	VT: HZ.:	DATE:	PROJECT NO.:
AJZ	–	02/11/20	–
CHKD:	APPD:	REV.:	NOTES:
DEP	DEP	–	–

FIGURE NO.: 1

LEGEND

GP-20 ■ 272 / 24.9 — PREVIOUSLY INSTALLED GEOPROBE WELL ID (2018) MAXIMUM DETECTED PFOS/PFOA CONCENTRATIONS (IN ng/L)

PFC-GP-97 ⊗ — PROPOSED GEOPROBE LOCATION. SAMPLE FOR PFAS

PFC-GP-98 ⊠ — PROPOSED GEOPROBE LOCATION. SAMPLE FOR PFAS AND 1,4-DIOXANE

RTW-1 ⊕ — PREVIOUSLY SAMPLED WELL ID MAXIMUM DETECTED PFOS/PFOA CONCENTRATIONS (IN ng/L)

GENERAL GROUNDWATER FLOW DIRECTION

SUSPECTED FOAM RELEASE AREA

PFAS — PER-AND POLYFLUOROALKYL SUBSTANCES

75
85
86
95
96
04

Technology Street
Temple Place
Brookhaven Avenue
Rowland Street
Bell Avenue
Weaver Drive
Grove Street
S. Railroad St.
East Princeton Avenue
Railroad

BGRR-GP-147 7 / 9
PFC-GP-132
PFC-GP-133
Training Area
Former Fire House
Former Roadway
Training Area
Former Water Supply Well 1
BGRR-GP-41 4.9 / 7.2
BGRR-GP- 148 63.7 / 14.7
PFC-GP-20 272 / 24.9
PFC-GP-21 5,210 / 161
PFC-GP-22 1,750 / 736
PFC-GP-23 3,360 / 290
PFC-GP-24 1,240 / 729
PFC-GP-25 11.6 / 17.6
PFC-GP-26 58.3 / 28.5
Storm Drainage Culvert
BGRR-GP- 149 9 / 4.8
BGRR-GP- 151 12.9 / 9.3
PFC-GP-97
PFC-GP-98
PFC-GP-99
PFC-GP-100
PFC-GP-101
PFC-GP-102
PFC-GP-103
PFC-GP-104
PFC-GP-105
PFC-GP-106
PFC-GP-107
PFC-GP-108
Former Building 96 Area
Former Supply and Material Area
EW-18 21 / 9
RTW-1 18 / 6
PFC-GP-109
PFC-GP-110
PFC-GP-111
PFC-GP-112
PFC-GP-113
PFC-GP-114
PFC-GP-115
RTW-2 7 / 4
RTW-3 9 / 4
RTW-4 40 / 14
HW
PFC-GP-116
PFC-GP-117
PFC-GP-118
PFC-GP-119
PFC-GP-120
PFC-GP-121
PFC-GP-122
PFC-GP-123
EW-16 9 / 5
PFC-GP-124
PFC-GP-125
PFC-GP-126
PFC-GP-127
PFC-GP-128
PFC-GP-129
PFC-GP-130
PFC-GP-131
EW-9 13 / 7
EW-10 9 / 5
EW-11 12 / 5

SCALE 0 200 400 FEET

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BROOKHAVEN NATIONAL LABORATORY
ENVIRONMENTAL PROTECTION DIVISION

TITLE:

FORMER FIREHOUSE AREA PFAS AND 1,4-DIOXANE CHARACTERIZATION

PROPOSED PHASE 5 GEOPROBE LOCATIONS

DWN:	VT: HZ.:	DATE:	PROJECT NO.:
AJZ	–	02/5/20	–
CHKD:	APPD:	REV.:	NOTES:
DEP	DEP	–	–

FIGURE NO.: 2